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ABSTRACT

This document presents an analysis of unit costs (annual cost per student) of engineering education in Ontario by degree and year level. All ordinary operating expenditures are covered including engineering department and faculty budgets, and all university overhead accounts such as library, administration, and plant maintenance costs. (HS)

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Committee of Presidents of Universities of Ontario
Comité des Présidents d'Université de l'Ontario

# A Method for Developing Unit Costs in Educational Programs

by
Ivor Wm. Thompson
and
Philip A. Lapp



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December 1970

# A METHOD FOR DEVELOPING UNIT COSTS IN EDUCATIONAL PROGRAMS

By

I. Wm. THOMPSON and P. A. LAPP

A REPORT SUBMITTED TO
THE COMMITTEE OF PRESIDENTS OF UNIVERSITIES OF ONTARIO
FOR THE STUDY OF ENGINEERING EDUCATION IN ONTARIO 1970-80

December, 1970

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| CPUO Report No. 70-1 | "Undergraduate Engineering Enrolment Projections for Ontario, 1970-1980," Philip A. Lapp. October, 1970. |
| CPUO Report No. 70-2 | "An Analysis of Projections of the Demand for Engineers in Canada and Ontario and An Inquiry into Substitution Between Engineers and Technologists," M. L. Skolnik and W. F. McMullen. November, 1970. |
| CPUO Report No. 70-3 | "A Method for Developing Unit Costs in Educational Programs," Ivor. Wm. Thompson and Philip A. Lapp. December, 1970. |

## PREFACE

At the 39th meeting (June, 1968) of the Committee of Presidents of Universities of Ontario, it was agreed that a comprehensive review and analysis should be undertaken of the universities' plans for the expansion of engineering facilities in the decade 1970-80. The Committee of Ontario Deans of Engineering was invited to undertake this review and analysis through the appointment of a full-time director. The study was to cover many areas of planning including curriculum, enrolment, research, staff and continuing education.

The Research Division of the Committee of Presidents offered to undertake several of the analytical sections of the study. One of the major investigations involved the derivation of unit costs (annual cost per student) by degree and year level taking into account cross-departmental and faculty teaching and all ordinary operating expenses including administrative overheads.

A summary description of the cost analysis is contained in Appendix H of the main report.[1] The purpose of this document is to provide a more detailed account of the analysis outlining the methodology, assumptions, procedures and data collection formats.

No actual input data or individual university results are presented in this report; only averages and ranges for the whole Ontario system of provincially-assisted engineering schools are included. In order to illustrate the methodology, we have created a model engineering faculty which is outlined in Appendix A. It is our opinion that the summary tables present results which will be beneficial to the university system without the need for presenting either the actual input data or the results for individual universities.

The presentation of detailed input data and resulting unit costs could lead to erroneous, and perhaps even invidious, comparisons. As will be described later there were several severe and limiting assumptions required in the analyses. This is not unusual in such cost analyses at this stage of their development, but because of these assumptions,

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[1] Ring of Iron, A Study of Engineering Education in Ontario, Committee of Presidents of Universities of Ontario, December 1970

the results should be interpreted as having a "range" of values - the range being dependent on the flexibility attached to the assumptions.

This report is intended to be detailed and in certain respects it may even seem pedantic. We have attempted to discuss each step thoroughly, even indicating several blind alleys which were pursued, in order to clarify the reasons for several of the assumptions.

The term "cost" is used throughout the study, albeit somewhat indiscriminately. In the business environment cost covers all the outlays for goods and services related to the product, excluding profit. A more precise term in the university context would be "expenditure", the amount each university spends from its income on engineering students. In a university environment it is not truly a cost because, given an increase in income, the universities would distribute all of this increase to the various programs. From the standpoint of this analysis, the word cost is adequate as perceived internally by each university, but viewed externally, costs should be interpreted as expenditures. All ordinary operating expenditures were covered including engineering department and faculty budgets, and all university "overhead" accounts (e.g. library, administration and plant maintenance).

The report is divided into seven major sections. There is a brief review of past methodologies, particularly the study conducted by the Association of Universities and Colleges of Canada (AUCC) in 1967. The second section covers the data collection forms and procedures together with the appropriate sample data for the model faculty. The two sections which follow outline the methodology and emphasize possible sources of error. Sections five and six contain the results and conclusions together with the limitations. An overview of the complete exercise is presented in section seven.

The authors hereby express their appreciation to Mr. Sheldon Zelitt for his efforts on the detailed calculations and to Professor Bernard Etkin, University of Toronto, for his derivation of the matrix format in Appendix C.

This is a report of a background study to <u>Ring of Iron: A Study of Engineering Education in Ontario</u> (Toronto: Committee of Presidents of Universities of Ontario, 1970). The views expressed herein are those of the authors and do not necessarily represent those of the Committee of Presidents of Universities of Ontario.

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## 1. REVIEW OF LITERATURE

To date an extensive number of articles have been published outlining methodologies for cost analyses. These range from a simple proration of all expenditures equally over all students, to complex distribution patterns having different allocation formulae for each expenditure account. The most comprehensive dissertation on the various methods used in the United States is provided by James L. Miller:[2]

> "A different procedure is used in each of the states with the single exception that essentially the same cost analysis procedure is employed in New Mexico and Colorado. The differences among procedures often are substantial... individual procedures will be considered in detail."

There would be no advantage in reviewing several methods in detail. Instead we shall concentrate on explaining one of the more familiar methods, termed the step-down method of cost analysis, which was employed by AUCC. This procedure was discussed by Leslie W. Knott and others:[3]

> "The cost centres (are) arranged in such order that the department which renders the greatest service to other departments in proportion to benefits received appears first in the arrangement. This would mean that activities representing primary cost centres would appear last. As the expenditures for each overhead or general service department, beginning with the first, are allocated to all other departments which it serves, the costing process for that cost centre is, for general purposes, considered closed. No further allocations are made to it. Under this system, expenditures for plant operation and maintenance, for example, might, as a first step, be allocated to all departments. When this process is completed, the plant management account is closed; nothing is added to it or deducted from it."

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2 Miller, James L., State Budgeting for Higher Education - The Use of Formulas and Cost Analysis, Institute of Public Administration, The University of Michigan, Ann Arbor, 1964.

3 Knott, Leslie W. et alia, Cost Analysis for Collegiate Programs in Nursing, Part I, Analysis of Expenditures, National League of Nursing, New York, 1956.

In the AUCC study all expenditures were grouped into the DBS-CAUBO[4] classifications as outlined in the Report of Financial Statistics of Universities and Colleges for the year 1966-67. All overhead accounts were then allocated in a predetermined order, as outlined by Knott, *et alia*, to the various cost centres. Several methods have been advanced in the literature for allocating these various accounts. In the AUCC study, for example, plant maintenance costs were allocated on the basis of square foot area of usable space. Library costs were allocated by charging expenditures for books, periodicals and processing directly to departments for which the literature was purchased, and by distributing all other expenditures on the basis of statistics on the relevant use of the library facilities by staff and students.

One of the most difficult accounts to distribute has always been academic expenditures. The treatment given in the AUCC study is typical of the approach used in many cost analyses; academic salaries are allocated to various activities such as instruction on the basis of a time distribution analysis of each faculty member. Invariably this approach has proven to be difficult and the results are often unreliable.[5] For these reasons, this approach was rejected. Instead we sought to establish a methodology that would not require such a detailed time analysis.

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4 DBS-CAUBO - Dominion Bureau of Statistics - Canadian Association of University Business Officers.

5 In one such survey known to the authors several faculty members were working more than 24 hours per day.

## 2. DATA COLLECTION

Data on student enrolments were extracted from submissions provided by each university. Examples of the data tables used are shown in Figures 1 and 1a. Budgetary information was provided in separate submissions by the Deans of Engineering and the university business officers; an example of the format used in collecting the financial information is presented in Figure 2.

To illustrate the methodology we have constructed a model engineering faculty offering two undergraduate programs, civil and mechanical engineering, and graduate programs in civil engineering. The undergraduate programs are two years in length with a common first year; the graduate program offers master's and doctoral degrees but they are of an unspecified length.

The engineering faculty is composed of three departments, Civil, Mechanical, and Metallurgy and Materials Science. Students in the engineering programs also take courses from one department outside the faculty - Mathematics. The necessary data collection forms (Tables 1, 2 and 3 of the submissions) have been completed for this model faculty together with the financial data and additional elements required to completely define the university (Appendix A).

FIGURE 1

DATA TABLES

TABLE 1[1] UNDERGRADUATE CLASSES 1969-70

| Class No. | Class Title | Given by Staff of the Dept. of | No. of Sections | Given to Students of the Dept. of | Number of Students from each Department | | | Total Annual Contact Hours per Student | | | Total Annual Staff Hours per Section | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Lect | Lab | Tut | Lect | Lab | Tut | Lect | Lab | Tut |
| | | | | | | | | | | | | | |

TABLE 2[1] GRADUATE CLASSES 1969-70

| Class No. | Class Title | Given by Staff of the Dept. of | No. of Sections | Given to Students of the Dept. of | Number of Students from each Department | | | Total Annual Contact Hours per Student | | | Total Annual Staff Hours per Section | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Lect | Lab | Tut | Lect | Lab | Tut | Lect | Lab | Tut |
| | | | | | | | | | | | | | |

1 Enumeration corresponds to that used in the questionnaire.

FIGURE 1A

DATA TABLES

TABLE 3[1] ENGINEERING ENROLMENTS

| Program | | 1960-1961 | | | 1968-1969 | | | | 1969-1970 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | FT | TOT | FTE | FT | TOT | FTE | | FT | TOT | FTE |
| Civil Engineering | | | | | | | | | | | |
| Undergraduate Yr. | 1 | | | | | | | | | | |
| | 2 | | | | | | | | | | |
| | 3 | | | | | | | | | | |
| | 4 | | | | | | | | | | |
| Graduate Yr. | 1 | | | | | | | | | | |
| | 2 | | | | | | | | | | |
| | 3 | | | | | | | | | | |
| | 4 | | | | | | | | | | |
| Beyond | 4 | | | | | | | | | | |

TABLE 5[1]

(LISTING OF ENGINEERING FACULTY MEMBERS)

1 Enumeration corresponds to that used in the questionnaire.

FIGURE 2

FINANCIAL DATA

EXPENDITURES BY DEPARTMENT

| Department[1] | Total Academic Salaries | Total Support Staff Salaries | Other Academic Expenditures | Total Departmental Expenditures | Percentage of Total Departmental Budget Allocated to Graduate Instruction | Sponsored or Assisted Research |
|---|---|---|---|---|---|---|
| | | | | | | |
| TOTALS | | | | | | |

1 Consider the faculty administration as a department

## 3. METHODOLOGY

Unfortunately the entire field of education suffers from a lack of standards and common definitions. For example, the term course may be used to describe either a single subject or, more generally, a group of subjects leading to a degree. Before proceeding with a discussion of the methodology, it will be necessary to define several of the more important terms used in the report.

In order to satisfy the requirements for a degree a student must complete a program of study. A program then consists of a package of courses (or classes or subjects) and/or research and/or field work. It is important to note that students enrol in a program of study, not a department or faculty. Faculties and constituent departments provide services to programs in the same manner as the library or registrar's office. Departments and programs may carry identical titles (Department of Mechanical Engineering compared to the degree program, Bachelor of Applied Science - Mechanical Engineering). However, this common nomenclature arises because students in a program historically take the majority of their courses from the department of the same name.

To complete a program each student must enrol in (and pass) a specified number of courses (classes or subjects - the three terms are used synonomously in this report). Thus a student enrolled in an honours B.A., majoring in history, might be required to take five history courses together with several elective courses.

In any course, the enrolment may be too large to instruct as a single unit either for pedagogical reasons or because of available facilities; the course may then be divided into two or more sections.

There are two methods of defining the teaching load imposed by any course, or section of a course: one based on the student time involved, and the other on the staff time. As an example consider a course given by the staff of Civil Engineering in which 200 students are enrolled. The course is divided into two sections and each section receives three hours of instruction per week. One

measure of teaching load is the number of weekly student-contact hours (commonly abbreviated to WSCH or SCH) which is equal to the product of the number of students enrolled and the hours per week the course is given. In this example there are 600 weekly student-contact hours (200 x 3). The alternate measure is the number of weekly staff-contact hours - the time spent by the staff instructing the course. Thus, there are 6 staff-contact hours a week (2 sections x 3 hours per week) involved in the example course.

This concept of staff-contact hour is important because it will be the unit introduced later for distributing academic expenditures. Several cost studies conducted in the past utilized student-contact hours for this purpose. However this approach was rejected because for obvious reasons we do not accept the premise that a course with 40 students enrolled would cost twice as much as the same course with 20 students. If the 40 students were sectioned into two groups, then the staff-contact hours would double; the workload in terms of teaching hours would double and we would then expect the cost to increase in the same proportion.

We recognize that this approach is not entirely correct - a true basis for distributing costs would be a combination of both student- and staff-contact hours. Forced to elect one method, we have chosen staff-contact hours as a better measure of cost than student-contact hours.

The following definitions were also used in the study:

| | | |
|---|---|---|
| Term | - | For programming purposes, a convenient division of the academic year, approximately thirteen weeks in Ontario. |
| Engineering faculty administrative unit (hereafter termed Engineering) | - | A group of resources (academic, support staff and materials) falling within an engineering faculty budget, under the administrative control of a dean or director, often divided into departments or discipline groups. |

The first step was to construct a "staff-contact hour matrix", commonly referred to as a cross-over matrix, illustrating the teaching services performed for the various programs by each department. All teaching services provided to engineering programs by outside departments and faculties were grouped into a single classification termed "other teaching". Services provided by Engineering for non-engineering programs were also grouped into one classification called "other programs". Where-ever possible, within the Engineering Faculty, distinctions were maintained between departments of the faculty and also between years in a program.

In the beginning, we also attempted to distinguish the option streams within each program. However, as the data reduction progressed it became obvious that this refinement would not be possible.

All computations were based on a full academic year. The total number of yearly staff-contact hours required for each course was computed by multiplying the annual staff hours per section by the number of sections. The staff-contact hours required for the lecture, laboratory and tutorial components of each course were computed separately because the annual staff hours per section could be different in each component (see Figure 1). Then, all staff-contact hours for a particular course were aggregated, and prorated among all students in the class. In the model, the course "Materials" given by the Department of Civil Engineering (Appendix A) requires 1,200 staff-contact hours for lectures (12 sections x 100 annual staff hours per section) and 7,200 staff-contact hours for laboratory teaching. The 8,400 total staff-contact hours (1,200 lecture + 7,200 laboratory) were prorated 7,000 hours (5/6) to the general first year engineering program and 1,400 hours (1/6) to the "other programs" category, i.e. to forestry which is a non-engineering program.

The enrolment in some courses offered in Ontario followed the pattern exhibited by the "Vibrations" course in the model; students from two different programs were enrolled in the lecture portion of the course but only students from one of these programs were enrolled in the laboratory. For this case, the staff-contact hours were computed for the lecture and laboratory component of the course but

not added. The lecture staff-contact hours were charged to student enrolment in the lecture portion, and the laboratory staff-contact hours charged to students enrolled in the laboratory part of the course.

This proration was carried to extremes in the study. In a class of 40 students consisting of 39 students from program A and one student from program B, one fortieth of the staff-contact hours would be charged to the student from program B. If this type of analysis were repeated, we would consider it reasonable to establish a lower bound (say 90%) such that if the percentage of students from any one program constituted more than this lower bound, then for cost purposes <u>all</u> the staff-contact hours would be charged to that program. Students from other programs would not be assessed under these circumstances. If several departments taught different sections of the same course, the relevant staff-contact hours were ascribed to the respective department.

The staff-contact hour matrix, completed for the course "Materials", is illustrated in Table 1, and the completed matrix for all courses is presented in Table 2. The vertical columns list the staff-contact hours taught by each department <u>to</u> each program. The horizontal rows contain, by year in program, the number of staff-contact hours provided <u>by</u> each department or group of outside faculties.

TABLE 1

STAFF-CONTACT HOUR MATRIX

("MATERIALS" COURSE ONLY)

| Program | Year in Program | Department: Civil | Mechanical | Metallurgy and Materials Science | Other | Totals |
|---|---|---|---|---|---|---|
| General | 1 | 7000 | | | | 7000 |
| Civil | 2 | | | | | |
| Civil | Grad. | | | | | |
| Mechanical | 2 | | | | | |
| Other | - | 1400 | | | | 1400 |
| Totals | | 8400 | | | | 8400 |

TABLE 2

STAFF-CONTACT HOUR MATRIX

(ALL COURSES)

| Program | Year in Program | Department: Civil | Mechanical | Metallurgy and Materials Science | Other | Totals |
|---|---|---|---|---|---|---|
| General | 1 | 7500 | 8000 | - | 2000 | 17500 |
| Civil | 2 | 4000 | 1250 | 3500 | - | 8750 |
| Mechanical | 2 | - | 4250 | 1400 | | 5650 |
| Civil | Grad. | 100 | - | - | - | 100 |
| Other | - | 1400 | 500 | - | - | 1900 |
| Totals | | 13000 | 14000 | 4900 | 2000 | 33900 |

In the cost study two matrices of the type illustrated in Table 2 were prepared for each university: one for all undergraduate engineering programs, and one for all formal instruction (courses, not research or thesis supervision) in the graduate programs. Because there is only one graduate course in the example, graduate programs have been combined with undergraduate. No distinction was made between different levels or years in the graduate sector. Therefore master's and doctoral candidates were considered under the single term "graduates". Graduate thesis supervision time was treated separately and will be discussed later.

The next stage involved the derivation of a cost per staff-contact hour for each department or teaching unit. It is recognized that the primary function of any academic department is to teach, and this function has two main components: formal classroom instruction, and research and thesis supervision. The first problem was to divide each department or faculty budget between formal instruction (represented by staff-contact hours), and research and thesis supervision. Normally this proration is based on a survey of the distribution of each faculty member's time between various activities. The results of these analyses conducted on a system basis have been unsatisfactory and inconclusive, so in lieu of this approach a variant of a technique used by the Committee of Vice-Chancellors and Principals in the United Kingdom was applied.

The purpose of the work in the United Kingdom was to identify, if possible, the objective factors influencing total departmental cost. In all the discipline areas studies it was found that costs are a linear function of student numbers, and no accurate separation of any research element could be achieved.

Because of the inter-departmental loading patterns existing in Ontario universities, it is not practical to identify each student with a particular department. For example, in the model, how many students should be credited to the Department of Civil Engineering? A specific number of students cannot adequately express the teaching

load placed on the department by the various programs. Instead we have assumed that the teaching load can be expressed by the number of staff-contact hours, and the number of graduate students supervised. Therefore, in the example, the teaching load for the Department of Civil Engineering is 13,000 staff-contact hours and 100 graduate students.

In contrast with undergraduate students each graduate was identified with a particular department for supervision purposes. In graduate programs, the thesis and research work is contained almost wholly within a single department and therefore the graduate student can be assumed to be attached to that department. Any formal or classroom instruction in which the student is engaged will still be credited to the department presenting the course.

The question now becomes, "how much of the departmental budget may be ascribed to staff-contact hours, and how much to the supervision of graduate students?". In the United Kingdom study this relationship was assumed to be linear; every additional undergraduate student required "X" additional dollars, and every graduate student "Y" additional dollars. This same relationship was assumed to exist in the engineering departments of the Ontario universities.

It was assumed that the teaching load of any department could be expressed in terms of "teaching equivalents" where one staff-contact hour is equal to one teaching equivalent, and one graduate student is equal to an unknown number of teaching equivalents, "K". Then if

$E_i$ = number of teaching equivalents for department i

$S_i$ = number of staff-contact hours taught by department i

$G_i$ = number of graduates supervised by department i

$$E_1 = S_i + K(G_i) \qquad (1)$$

(in tne United Kingdom study, $S_i$ is replaced by the number of undergraduate students).

A separate value of K was not determined by department. A constant relationship was assumed for all engineering departments in the Ontario universities. For any engineering department, the cost of one graduate student, exclusive of classroom instruction, was assumed to be K times the cost of one staff-contact hour. If

$B_i$ = budget of department i

$a_i$ = cost per teaching equivalent in department i,

and $c_i$ = constant

then

$$B_i = c_i + a_i (E_i)$$

$$= c_i + a_i (S_i) + a_i K (G_i) \qquad (2)$$

Before proceeding to a discussion of how a value for K was derived, a few comments should be directed to the financial information which was collected. Each year the Ontario universities submit to the Department of University Affairs (Government of the Province of Ontario) a statement of expenditures, by major classification, for the past year and budget estimates for the forthcoming year. For the 1969-70 session, the Department of University Affairs used a classification scheme which had been proposed by the Canadian Association of University Business Officers (CAUBO) and which contained the following categories:

1. Academic (except Library)
2. Library
3. Student Services
4. Scholarships, Bursaries and Prizes
5. Sponsored or Assisted Research
6. Administration
7. Plant Maintenance
8. General Expenditures
9. Net Deficit on Ancillary Enterprises.

The academic expenditure account was further categorized as follows:

1. Academic (except Library)
   - (a) Salaries
     - (i) Academic Staff
     - (ii) Supporting Staff
   - (b) Fringe Benefits
   - (c) Other Academic Expenditures

We shall be concerned first with the academic expenditure category. Departmental budgets are usually contained entirely within this category. There are a few exceptions where the departmental budget contains allocations for central library services, computing services and other central ancillary enterprises. Where this was the case, the departments were asked to indicate these appropriations which were deducted from the departmental budget for the purpose of allocating the academic expenditure category. Thus an expenditure such as central library facilities would have involved a double counting if the charge had not been deleted from the departmental budget. The financial information for the study was obtained from two sources, the Canadian Association of University Business Officers (CAUBO) forms and the responses to the forms presented in Figure 2.

Another problem arose because the total academic expenditure account for each university contains more than the sum of all faculty budgets. Areas such as the President's Office and the administration of the School of Graduate Studies are often charged to this account. Part of these expenditures should be distributed to Engineering. Since data were not available on their magnitude they have not been accounted for in the analysis. As an extreme upper limit they should represent no more than $50 per student.

The Engineering faculty budgets consisted of the individual departmental budgets plus the faculty office budget containing items such as the Dean's salary and costs of the faculty administration office. The faculty office budget was distributed among departments on the basis of the percentage contribution of each department's budget to the total of all departmental budgets in the faculty.

In several faculty budgets there were appropriations that were neither faculty administration nor departmental budgets. "Media Resources" was one example of this type of appropriation. Each of these cases was treated separately applying the rule that where

possible the amounts should be allocated to those units bearing the responsibility for the costs. There are too many cases to discuss separately in this text, and therefore one example is cited as an illustration; i.e. special counselling service established by the faculty as an independent unit to assist first year students in selecting courses and adjusting to the university environment. This appropriation would be distributed equally to all first year engineering students.

If fringe benefits were not included in the salary figures, universities were requested to provide either a percentage allocation for fringe benefits, or a fixed sum that was then distributed equally over all salaries, both academic and non-academic.

In the model, Civil Engineering has an appropriation of \$600,000, Mechanical Engineering, \$400,000, Metallurgy and Materials Science, \$200,000 and the faculty administration, \$300,000 for a total faculty budget of \$1,500,000 (Appendix A). The faculty administration budget of \$300,000 would be prorated one-half (600,000/1,200,000 = 1/2) to Civil Engineering, one-third to Mechanical Engineering and one-sixth to Metallurgy and Materials Science.

Equation (2) can now be completed for each department.

$$B_i = c_i + a_i(S_i) + a_iK(G_i) \qquad (2)$$

Civil Engineering
$$750{,}000 = c_1 + a_1(13{,}000) + a_1K(100) \qquad (2a)$$

Mechanical Engineering
$$500{,}000 = c_2 + a_2(14{,}000) \qquad (2b)$$

Metallurgy and Materials Science
$$250{,}000 = c_3 + a_3(\ 4{,}900) \qquad (2c)$$

This system of equations cannot be solved for a unique value of K. To estimate the value of K for the Ontario engineering schools, a linear regression was established between teaching equivalents and <u>the teaching salary component</u> of the departmental budget for the thirty-seven different departments involved in the study. The teaching salary component was used because it was felt that this portion was more directly related to teaching than the total departmental budget.

The teaching salary component was derived from the academic salaries category of the departmental budget. In their submissions the universities were asked for an approximate time distribution of Engineering faculty members. It was concluded that an average of 70 percent of a faculty member's time is devoted to teaching and supervision, with the balance being spent on administrative duties (15 percent), consulting (10 percent) and professional and public service (5 percent). Therefore 70 percent of academic salaries was used in the determination of K.

The system of equations to be solved (2a, 2b, and 2c) becomes:

$$280{,}000 = c_1 + b_1(13{,}000) + b_1K(100) \quad (3a)$$
$$210{,}000 = c_2 + b_2(14{,}000) \quad (3b)$$
$$105{,}000 = c_3 + b_3(\ 4{,}900) \quad (3c)$$

The $b_i$'s can be considered to be the "academic salaries component" of the teaching equivalents costs ($a_i$'s). For any selected value of K the resulting teaching equivalents can be regressed with the salaries component of the departmental budget. The system of equations in the example does not have a unique solution (there will always be 2n + 1 unknowns for this system of n equations) nor is this a good example to demonstrate the linear regression technique because K appears in only one of the equations.

Consider the following example with a system of three equations each involving the variable K:

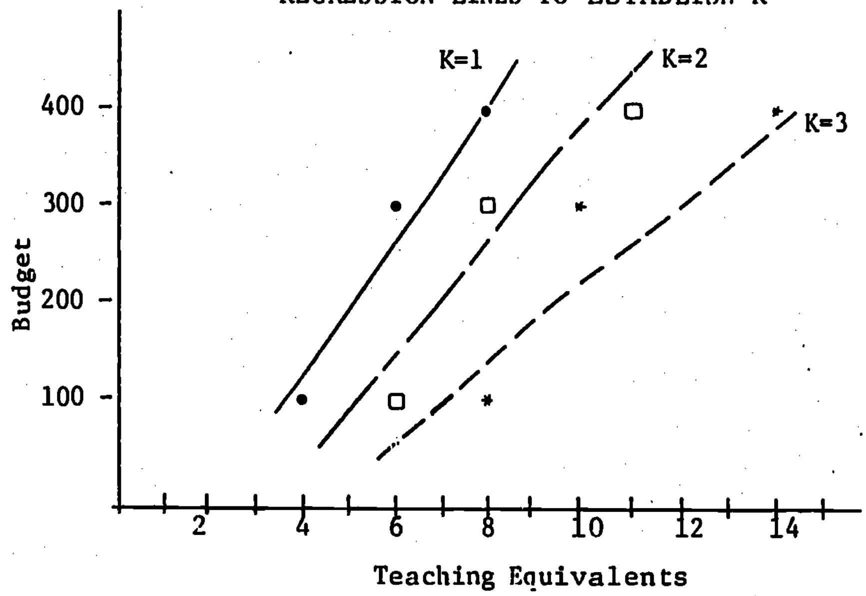
$$100 = c_1 + x_1(2 + 2K) \quad (4a)$$
$$300 = c_2 + x_2(4 + 2K) \quad (4b)$$
$$400 = c_3 + x_3(5 + 3K) \quad (4c)$$

| Department | Budget | Teaching Equivalents | | |
|---|---|---|---|---|
| | | K = 1 | K = 2 | K = 3 |
| 1 | 100 | 4 | 6 | 8 |
| 2 | 300 | 6 | 8 | 10 |
| 3 | 400 | 8 | 11 | 14 |

The regression lines for K equal to one, two and three are illustrated in Figure 3.

FIGURE 3

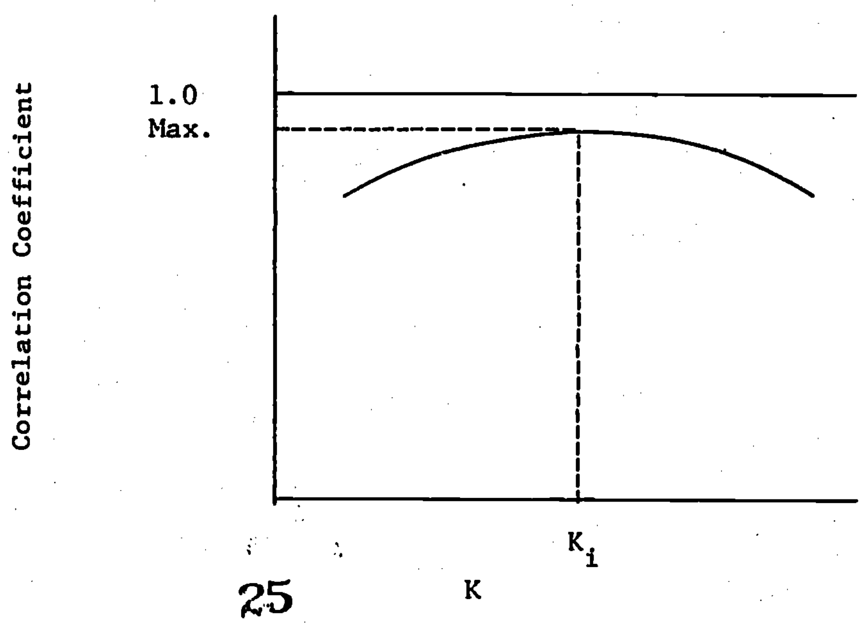
REGRESSION LINES TO ESTABLISH K




The estimate of K that yielded the highest correlation coefficient was selected as the final value. When the selected values of K were plotted against the corresponding correlation coefficients a curve similar to that presented in Figure 4 was derived.

FIGURE 4

DETERMINATION OF K



For the example shown in Figure 4 the value selected would be $K_i$. One situation that must be checked is the possibility of multiple values for K, for if $K_i$ produces a maximum then perhaps $2K_i$ or $10K_i$ or, in the general case, $nK_i$ may also produce a maximum. This was tested in the analysis, and when no multiple value was found the subject was not pursued further. (We did not consider what course of action would have been necessary had we discovered multiple values.)

The best linear regression yielded a correlation coefficient of 0.98, for thirty-seven points, and a final value of K equal to 150. This corresponds to three hours per week per graduate student for a fifty week year. In order to achieve this result it was necessary to divide the data into two groups. When the data were treated as a single set of thirty-seven elements, the maximum correlation coefficient achieved was 0.93 for K equal to 180. However, with the exception of three departments, <u>all</u> the departments of any one faculty were either entirely above the regression line or entirely below. This suggested the existence of two different "policies" or "internal weightings" for graduate students. The data were divided into two groups (fifteen points lying above the regression line, and twenty-two points below) and separate K values were determined for each set. The resulting values were K equal to 190 and 115.

Further pursuit of the two-value theorem for K would have inferred the recognition and assumption of two distinct policies regarding graduate engineering studies in the Ontario universities. Additional data such as the ratio of graduate student to total student enrolment tends to confirm the theorem of two policies or rather two implicit relationships. However, there was insufficient data to state unequivocally that these two relationships existed. Therefore we continued to consider the data in two sets but established a single value of K corresponding to the highest correlation coefficient for the two sets considered together.

This value was 150 (staff-contact hours per student per year). This is equivalent to saying that each graduate student requires an average of three hours of supervision per week for a fifty week year.

The teaching load of any department can now be expressed completely by teaching equivalents: the sum of staff-contact hours and the product of the K factor (150) and the number of graduate students supervised in that department. In this analysis the value of K was derived only for the Engineering faculties and schools included in the study. The same value is not necessarily valid for other faculties in the Ontario universities or Engineering faculties outside the Province of Ontario.

In using this approach we have assumed that there exists an implicit relationship in the Ontario schools of engineering such that the incremental cost to a department is the same whether one graduate student is added or the teaching load is increased by 150 (the K factor) staff-contact hours, averaged for the set of thirty-seven departments studied.

With a value for K established, it is now possible to derive the cost per teaching equivalent for each department. If we assume that the same value K is applicable to the model, the system of equations 2a, 2b, and 2c can be rewritten:

$$750{,}000 = a_1(13{,}000) + a_1(15{,}000) \quad (5a)$$

$$500{,}000 = a_2(14{,}000) \quad (5b)$$

$$250{,}000 = a_3(4{,}900) \quad (5c)$$

(assume $c_i$ for i equal to 1,2 and 3 equal to zero, and so attribute all costs to the teaching equivalents).

$$a_1 = \$26.79$$

$$a_2 = \$35.71$$

$$a_3 = \$51.02$$

In the model, the cost of teaching one course in civil engineering for one hour is \$26.79. Thesis supervision and research account for 54 percent (15,000/28,000) of the total departmental budget of Civil Engineering, including faculty overheads.

This procedure yielded a tabulation of instruction costs per staff-contact hour for each department within Engineering. It was also necessary to develop the cost per staff-contact hour for courses taught by other faculties. The first step was to derive an average cost per staff-contact hour for Engineering. This was derived by dividing the total faculty budget by the total teaching equivalents summed over all engineering departments. For the model the average cost was $31.98 ($1,500,000/46,900 teaching equivalents).

The cost per staff-contact hour for other faculties was assumed to be equal to the average Engineering cost per staff-contact hour, adjusted by the quotient of the student to staff ratio in Engineering divided by the student to staff ratio of the whole university. The reasoning behind this approach was that the average class size has the greatest influence on unit costs as will be shown later, and average class size is directly related to the student to staff ratio. Therefore the student to staff ratios were used as a proxy measure for comparing costs. For the model, the overall student to staff ratio was 16:1 (10,000/625); the ratio for the Engineering faculty, 20:1 (1,000/50). Thus the cost per staff-contact hour in the other faculties was set equal to $39.98 ($31.98 x 20/16.) (In retrospect it could have been argued that the student to staff ratio of the entire university should have been calculated exclusive of the engineering students and faculty.)

Every element of the staff-contact hour matrix was multiplied by the appropriate departmental instruction cost per staff-contact hour to produce a cost distribution matrix (Table 3).

TABLE 3

DEPARTMENTAL COST DISTRIBUTION MATRIX
(excluding thesis supervision and research)

| Program | Year in Program | FTE Enrolment | Department | | | | Total Cost | Cost per Student |
|---|---|---|---|---|---|---|---|---|
| | | | Civil $ | Mechanical $ | Metallurgy and Materials Science $ | Other $ | $ | $ |
| General | 1 | 500 | 200,893 | 285,713 | - | 79,950 | 566,556 | 1133 |
| Civil | 2 | 250 | 107,143 | 44,644 | 178,571 | - | 330,358 | 1321 |
| Mechanical | 2 | 150 | - | 151,785 | 71,429 | - | 223,214 | 1488 |
| Civil | Grad. | 100 | 2,679 | - | - | - | 2,679 | 26.79 |
| Other | | - | 37,500 | 17,858 | - | - | | N.A. |
| TOTALS [1] | | 900 | 308,036 | 482,142 | 250,000 | 79,950 | 1,120,128 | 1245[2] |

1 excluding graduate and "other"
2 average cost per undergraduate student

The unit costs were computed by adding the costs along each horizontal row, and dividing the results by the corresponding number of full-time equivalent (FTE) students in each program and year. The same procedure was followed for graduate programs in order to generate the instruction portion of unit costs to which must be added the graduate supervision costs - that portion of the total departmental budget devoted to graduate thesis supervision and research divided by the corresponding number of FTE graduate students. This sum yields unit cost (excluding research grants) for each graduate program in each university.

In the model, the total cost for the second year of the mechanical engineering program is $223,214 distributed over 150 students for a unit cost of $1,488. The unit cost for graduate students in civil engineering is composed of an instructional cost per student of $26.79 ($2679/100) and a thesis supervision and research cost of $4,018 ($401,785/100) for a total cost of $4,045.

It was assumed that there were three components (excluding university overhead) of total unit cost in the graduate sector: instructional cost, thesis supervision and research, and assisted research. A compilation of assisted research grants for 1969-70 was provided on a departmental basis. The total departmental grant was divided by the appropriate number of graduate students and the result added to the other two component costs to yield a unit cost including assisted research. (For Engineering, assisted research money is derived principally from the National Research Council.) The department of Civil Engineering, in the model, received assisted research monies of $300,000. Prorated over the graduate students in civil engineering this would raise the cost to $7,045 ($4,045 + $300,000/100).

To this point we have discussed the distribution of two accounts: academic expenditures and assisted research. The remaining accounts (listed on page 14) are commonly referred to as university overhead. The usual method of handling such accounts is to establish a distribution formula for each one. Maintenance and physical plant, for example, may be distributed on the basis of the percentage of floor area within the

jurisdiction of the unit under study. During our discussions with the various finance officers, we could not obtain any common agreement on methods for distributing these overhead accounts.

The only agreement we could achieve, and to which we subscribe, was to distribute all overhead accounts equally among all students, because of inherent limitations in the present university information systems. For engineering, this would imply that the library cost per student was equal to that for a student in the humanities or social sciences, but the cost per student for computing services is also considered the same for both types of students. There is a trade-off between these accounts and it is our opinion that further accuracy would not be achieved by introducing different distribution formulae for each account.

Instead, the unit costs in each department were increased by a fixed percentage derived for each university. The percentages were set equal to the sum of academic expenditures and assisted research divided by total ordinary operating expenditures.

Example: Let A = academic expenditures
R = assisted research
O = other expenditures
T = total expenditures
P = percentage to be applied for overhead

$$A + R + O = T$$

Define:

$$P = (A + R)/T$$

$$T = (A + R)/P$$

Model University:

2nd Year Civil Engineering Unit Cost = \$1,321
Assisted Research = \$0
Percentage (Appendix A) = 70%
Total Unit Cost = \$1,887

The percentages for Ontario ranged from 55 to 75 percent depending on the size of the institution; the average was 70 percent. The percentages were derived from the UA-4 reporting forms (CAUBO forms for 1969-70) submitted to the Department of University Affairs by each

university. The total unit costs for the engineering programs in the model university are presented in Table 4.

Table 5 is a summary of average total unit costs by discipline and year, weighted in each case by the number of students for the engineering programs in the Ontario universities. Three values are displayed: the Ontario average, the maximum value and the minimum value.

TABLE 4

TOTAL UNIT COSTS

| Program | Year in Program | Academic Cost: Under-Graduate | Academic Cost: Graduate (Excluding Assisted Research) | Academic Cost: Graduate (Including Assisted Research) | Overhead Factor | Total Unit Cost: Under-Graduate | Total Unit Cost: Graduate (Excluding Assisted Research) | Total Unit Cost: Graduate (Including Assisted Research) |
|---|---|---|---|---|---|---|---|---|
| General | 1 | 1133 | - | - | .7 | 1619 | - | - |
| Civil | 2 | 1321 | - | - | .7 | 1887 | - | - |
| Mechanical | 2 | 1488 | - | - | .7 | 2126 | - | - |
| Civil | Grad. | - | 4045 | 7045 | .7 | - | 5779 | 10064 |
| Average (Excluding Graduate) | | 1245 | - | - | .7 | 1779 | - | - |
| Average (Including Graduate) | | 1524 | | 1824 | .7 | 2177 | | 2606 |

TABLE 5

UNIT COSTS BY DISCIPLINE, YEAR AND NUMBER OF STUDENTS
1969-70

| PROGRAM | YEAR | NO. OF FTE STUDENTS | ONTARIO AVERAGE | MAXIMUM | MINIMUM | MAXIMUM / MINIMUM |
|---|---|---|---|---|---|---|
| Chemical Engineering | I | 444 | $ 920 | $ 1,740 | $ 360 | 4.8 |
| | II | 383 | 1,200 | 5,490 | 550 | 10.0 |
| | III | 228 | 2,800 | 4,660 | 990 | 4.7 |
| | IV | 237 | 2,100 | 8,840 | 1,230 | 7.2 |
| | ALL | 1,292 | 1,550 | 8,840 | 360 | 24.6 |
| Graduate - excluding assisted research | ALL | 320 | 9,190 | 14,730 | 5,760 | 2.6 |
| - including assisted research | ALL | | 15,740 | 20,800 | 11,440 | 1.8 |
| Civil Engineering | I | 495 | 1,090 | 1,740 | 360 | 4.8 |
| | II | 505 | 1,500 | 5,980 | 980 | 6.1 |
| | III | 339 | 1,450 | 2,780 | 750 | 3.7 |
| | IV | 243 | 2,040 | 6,310 | 840 | 7.5 |
| | ALL | 1,582 | 1,440 | 6,310 | 360 | 17.5 |
| Graduate - excluding assisted research | ALL | 376 | 8,850 | 14,350 | 6,680 | 2.1 |
| - including assisted research | ALL | | 14,110 | 23,120 | 9,820 | 2.4 |
| Electrical Engineering | I | 540 | 1,060 | 1,430 | 360 | 4.0 |
| | II | 560 | 1,010 | 1,500 | 700 | 2.1 |
| | III | 392 | 1,380 | 4,020 | 1,200 | 3.4 |
| | IV | 317 | 1,660 | 4,150 | 890 | 4.7 |
| | ALL | 1,809 | 1,220 | 4,150 | 360 | 11.5 |
| Graduate - excluding assisted research | ALL | 413 | 8,150 | 13,700 | 4,370 | 3.1 |
| - including assisted research | ALL | | 12,180 | 19,510 | 8,800 | 2.2 |
| Mechanical Engineering | I | 529 | 1,050 | 1,430 | 360 | 4.0 |
| | II | 549 | 1,250 | 1,700 | 530 | 3.2 |
| | III | 366 | 2,010 | 3,320 | 940 | 3.5 |
| | IV | 322 | 1,800 | 6,020 | 1,000 | 6.0 |
| | ALL | 1,766 | 1,450 | 6,020 | 360 | 16.7 |
| Graduate - excluding assisted research | ALL | 278 | 9,410 | 15,270 | 6,400 | 2.4 |
| - including assisted research | ALL | | 14,190 | 15,780 | 9,910 | 1.6 |
| Metallurgical and Materials Engineering | I | 61 | 930 | 1,430 | 360 | 4.0 |
| | II | 61 | 1,520 | 2,560 | 880 | 2.9 |
| | III | 33 | 3,940 | 6,120 | 210 | 29.1 |
| | IV | 38 | 6,850 | 14,460 | 4,470 | 3.2 |
| | ALL | 193 | 2,800 | 14,460 | 210 | 68.9 |
| Graduate - excluding assisted research | ALL | 100 | 10,450 | 17,000 | 7,190 | 2.4 |
| - including assisted research | ALL | | 21,780 | 35,290 | 15,180 | 2.3 |
| All Engineering Programs | I | 2,621 | 1,030 | 1,960 | 360 | 5.4 |
| | II | 2,450 | 1,270 | 18,760 | 530 | 35.4 |
| | III | 1,709 | 1,850 | 6,120 | 210 | 29.1 |
| | IV | 1,446 | 2,040 | 14,460 | 840 | 17.2 |
| | ALL | 8,226 | 1,450 | 18,760 | 210 | 89.3 |
| Graduate - excluding assisted research | ALL | 2,089 | 8,190 | 17,000 | 4,370 | 3.9 |
| - including assisted research | ALL | 10,315 | 13,460 | 35,290 | 8,100 | 4.4 |

4. SOURCES OF ERROR

This method of computing unit costs involved certain assumptions whose validity is open to discussion. The most debatable assumption is the method for prorating the departmental budget between instruction and graduate supervision, where it was assumed that each graduate student absorbs a fixed number of staff hours annually for graduate supervision and research. The validity of this assumption was tested by the dispersion of the actual departmental budgets from the values calculated using the K factor. For the set of thirty-seven departments in Ontario, the correlation coefficient was 0.98, and over 80 percent of the points fell within an 18 percent band about the regression line. Anomalies will occur in some departments because of the mixture of thesis and course-work master's degree students, and variations in thesis supervision practice among academic staff.

A second assumption used in the K value determination was the portion of academic salaries devoted to either instruction or graduate supervision, assumed to be 70 percent. Obviously, this will vary among departments and individuals within a department. The figure was selected on the basis of the submissions without a detailed time distribution study of university staff in all of the universities.

These two assumptions were used to calculate the percentage split of the departmental budget between instruction and graduate supervision. In general, the calculated percentages of departmental budget devoted to graduate instruction were slightly higher than estimated values provided by some universities, the average difference being 8 percent.

A third assumption was the use of student to staff ratios to compute the contact hour cost for departments outside of Engineering. There would appear to be few alternatives until a similar cost study is conducted for all other faculties. The student to staff ratios were readily available though they reflect relative costs only if staff and teaching policies are similar throughout the entire university.

A fourth assumption was the uniform division of assisted research monies among all graduate students within the department. The validity of this may be questioned in specific instances, but no reasonable alternative was apparent from available data.

The final significant assumption was the application of expenditures to overhead accounts. These were applied to the unit costs developed from the departmental budgets and included costs of library, student services, scholarships, bursaries, administration, plant maintenance, general expenditures and net deficit on ancillary enterprises, all expressed as a percentage of the total expenditure for each university. Errors could have been introduced in this final calculation since some of the expenditures covered by the overhead accounts in the UA-4 forms often are credited to the departmental budget. However, most universities did provide data on these additional costs, including them in the departmental budgets. In these cases, such costs were removed and were not counted twice.

All these assumptions create possible errors in the calculations of cost per contact hour. Errors may also be introduced in the compilation of staff-contact hours per student where the data from the tables in Figure 1 may contain errors and omit complete classes. If classes given by the staff in Engineering were omitted, only the distribution of costs among the programs would be altered, but not the average cost per engineering student.

Undergraduate thesis contact hours were not reported by all universities. For this reason, it was decided to omit these hours from the undergraduate contact hour matrix so that undergraduate thesis costs were distributed evenly over all teaching equivalents in Engineering. Consequently, relative fourth year costs may be reduced slightly.

Omitted classes given by the faculties other than Engineering would be excluded from the total and lost. In several cases it was found that classes taught to graduate students by staff from other than Engineering departments were omitted, and in these cases the final unit cost figures will be low.

## 5. DERIVATION OF POLICY VARIABLES

A principal purpose of the cost study was to identify specific quantities that could be measured easily and then used in the establishment of administrative policies and practices. Eight of these policy variables were identified and each can be combined in a direct way to yield approximations to unit cost, so that it is theoretically possible to blend each component in an optimum fashion, consistent with fixed quality standards, to minimize unit cost. These quantities, or policy variables, can be derived from the unit cost computation described in Section 3.

The administrator can develop approximate unit costs without the necessity of completing either a detailed cost study or an inter-departmental staff-contact hour matrix, since values for the eight policy variables can often be determined from available data. There are three levels of policy variables: those that can be established at the departmental level, those controllable at the faculty level and those that are general university policy (several of the policy variables can be controlled or established at more than one administrative level). We shall be concerned first with identifying the policy variables at the departmental level.

The unit cost of each undergraduate program consists of three components: the cost attributed to the various departments within Engineering, to other faculties, and to the overhead accounts. We shall first introduce the policy variables that are derived from the Engineering faculty component of unit cost.

The contribution of each department within Engineering to the instruction cost for any year of a program can be expressed

by the following variables:

$C(j)$ = instruction cost per staff-contact hour in department j

$H(t,i,j)$ = staff-contact hours devoted to year t of program i by department j

$E(t,i)$ = enrolment in year t of program i

$D(t,i,j)$ = instruction cost per student in year t of program i for department j

$$D(t,i,j) = C(j) \times \frac{H(t,i,j)}{E(t,i)}$$

The departmental instruction cost per staff-contact [C(j)] is equal to that portion of the departmental budget devoted to formal instruction divided by the total number of instructional staff-contact hours taught by the department. The formal instruction portion of the departmental budget was obtained from the K factor analysis where it was assumed that the budget was divided between formal instruction and graduate supervision. Define:

$G(j)$ = number of graduate students supervised in department j

$Q(j)$ = total departmental teaching equivalents

$$Q(j) = \sum_t \sum_i H(t,i,j) + K\, G(j)$$

$I(j)$ = instruction factor for department j

$S(j)$ = graduate student factor for department j

$$I(j) = \frac{\sum_t \sum_i H(t,i,j)}{Q(j)}$$

$$S(j) = \frac{K \times G(j)}{Q(j)}$$

$$1 = I(j) + S(j)$$

B(j) = budget for department j
X(j) = number of FTE faculty in department j

$$C(j) = \frac{B(j) \times I(j)}{\sum_t \sum_i H(t,i,j)}$$

Dividing denominator and numerator by X(j):

$$C(j) = \frac{B(j)/X(j)}{\sum_t \sum_i H(t,i,j)/X(j)} \times I(j)$$

$$D(t,i,j) = \frac{B(j)/X(j)}{\sum_t \sum_i H(t,i,j)/X(j)} \times I(j) \times \frac{H(t,i,j)}{E(t,i)} \qquad (6)$$

$$\begin{array}{c}\text{Departmental}\\\text{Instruction}\\\text{Cost per}\\\text{Student in}\\\text{Year t of}\\\text{Program i}\end{array} = \frac{\begin{array}{c}\text{Departmental}\\\text{Budget per}\\\text{FTE Staff}\end{array}}{\begin{array}{c}\text{Departmental}\\\text{Staff-Contact}\\\text{Hours per FTE}\\\text{Staff}\end{array}} \times \begin{array}{c}\text{Departmental}\\\text{Instruction}\\\text{Factor}\end{array} \times \frac{\begin{array}{c}\text{Staff-Contact}\\\text{Hours Devoted}\\\text{to Year t of}\\\text{Program i}\end{array}}{\begin{array}{c}\text{Number of}\\\text{Students in}\\\text{Year t of}\\\text{Program i}\end{array}}$$

Three policy variables now emerge that can be controlled at the departmental level

1. Departmental Salary Load = departmental budget per FTE staff member (this terminology is used because the major proportion of a departmental budget is salaries).

2. Departmental Instruction Work Load = total departmental staff-contact hours per FTE staff member.

3. Departmental Instruction Factor = portion of the departmental budget devoted to formal instruction.

The contribution of each engineering department to the cost of year t of program i can be aggregated to derive the total cost per student. Consider one segment of a cost per student distribution matrix (Figure 5).

FIGURE 5

SAMPLE SECTION OF A UNIT COST DISTRIBUTION MATRIX

| | Enrolment | | Department j | | Total cost |
|---|---|---|---|---|---|
| | | | | | |
| Program i | E(t,i) | | H(t,i,j) x C(j) | | T(t,i) |
| | | | | | |

Define:

$$T(t,i) = \text{total cost for year t of program i}$$

$$= \sum_j \left[H(t,i,j) \times C(j)\right]$$

$$\bar{U}(t,i) = \text{unit cost in year t of program i.}$$

$$\bar{U}(t,i) = \frac{\sum_j \left[H(t,i,j) \times C(j)\right]}{E(t,i)} \qquad (7)$$

As an example, consider the second year of the mechanical engineering program in the model:

$$j = \text{Mechanical Engineering Department}$$
$$j+1 = \text{Metallurgy and Materials Science Department}$$

$$\bar{U}(t,i) = D(t,i,j) + D(t,i,j+1)$$

$$\bar{U}(t,i) = \frac{B(j)/X(j)}{\sum_t \sum_i H(t,i,j)/X(j)} \times I(j) \times \frac{H(t,i,j)}{E(t,i)}$$

$$+ \frac{B(j+1)/X(j+1)}{\sum_t \sum_i H(t,i,j+1)/X(j+1)} \times I(j+1) \times \frac{H(t,i,j+1)}{E(t,i)}$$

$$= \frac{500{,}000/X(j)}{14{,}000/X(j)} \times 1 \times \frac{4250}{150} + \frac{250{,}000/X(j+1)}{4{,}900/X(j+1)} \times 1 \times \frac{1400}{150}$$

$$= \$1012 + \$476$$

$$\bar{U}(t,i) = \$1488 \quad \text{(compare to \$1488, page 26)}$$

Equations (6) and (7) are valid not only for any one year of a program, but also for an average of all years in one program, or for an average of all programs for one particular year. Once again this can be demonstrated by a sample section of a cost distribution matix for a program requiring two years (Figure 6).

FIGURE 6

SAMPLE SECTION OF A UNIT COST DISTRIBUTION MATRIX

| | Enrolment | | Department j | | Total Cost |
|---|---|---|---|---|---|
| Program i, year t | E(t,i) | | H(t,i,j) x C(j) | | T(t,i) |
| Program i, year t+1 | E(t+1,i) | | H(t+1,i,j) x C(j) | | T(t+1,i) |

$\bar{U}(i)$ = unit cost in program i

$$= \sum_t T(t,i) \Big/ \sum_t E(t,i)$$

$$\bar{U}(i) = \frac{\sum_t \sum_j [H(t,i,j) \times C(j)]}{\sum_t E(t,i)} \tag{8}$$

$\bar{U}(t)$ = unit cost in year t averaged over all programs

$$= \sum_i T(i,i) \Big/ \sum_i E(t,i)$$

$$\bar{U}(t) = \frac{\sum_i \sum_j [H(t,i,j) \times C(j)]}{\sum_i E(t,i)} \tag{9}$$

A cost per student averaged over all programs and all year levels can also be derived:

$\bar{U}$ = unit cost per student averaged over all programs and all year levels

$$= \sum_t \sum_i T(t,i) \Big/ \sum_t \sum_i E(t,i)$$

$$\bar{U} = \frac{\sum_t \sum_i \sum_j [H(t,i,j) \times C(j)]}{\sum_t \sum_i E(t,i)} \tag{10}$$

We have identified three policy variables affecting the unit cost that are controllable at the departmental level: the average departmental expenditure per FTE staff member, the average number of staff-contact hours per FTE staff member and the proportion of a department's budget that can be attributed to formal instruction. To introduce the remaining policy variables, it will be more convenient to work with a unit cost averaged over all programs and

all years. The expression:

$$\text{Departmental Instruction Cost per Staff-Contact Hour} = \frac{\text{Departmental Budget per FTE Staff Member}}{\text{Departmental Staff-Contact Hours per FTE Staff Member}} \times \text{Departmental Instruction Factor}$$

or

$$C(j) = \frac{B(j)/X(j)}{\sum_{t}\sum_{i} H(t,i,j)/X(j)} \times I(j)$$

can also be written for the faculty level:

$$\text{Faculty Instruction Cost per Staff Contact-Hour} = \frac{\text{Faculty Budget per FTE Staff Member}}{\text{Faculty Staff-Contact Hours per FTE Staff Member}} \times \text{Faculty Instruction Factor}$$

or

$$C^* = \frac{\sum_{j} B(j) \Big/ \sum_{j} X(j)}{\sum_{t}\sum_{i}\sum_{j} H(t,i,j) \Big/ \sum_{j} X(j)} \times I^*$$

where $I^*$ = Faculty instruction factor

$$= \frac{\sum_{t}\sum_{i}\sum_{j} H(t,i,j)}{\sum_{t}\sum_{i}\sum_{j} H(t,i,j) + K \sum_{j} G(j)}$$

Two additional policy variables can now be introduced:

4. Student Load = Student hours per year

5. Average Section Size = Ratio of the number of students in any section to the number of staff teaching the section, but averaged over all sections taught by the faculty or department. For example, in a lecture section of 100 students, the section size would be 100; whereas in a laboratory section of 100 students with ten instructors, the average section size would be ten. The average section size can be regarded as the average student to staff ratio in all sections for any year of a program.

If:

$Y(t,i,j)$ = yearly student hours required by year t in program i from department j

$A^*$ = average section size (average for the faculty)

then,

$$\text{Average Section Size} = \frac{\text{Average Yearly Class Hours per Student} \times \text{Number of Students}}{\text{Total Staff-Contact Hours}}$$

so that

$$\text{Staff-Contact Hours per Student} = \frac{\text{Average Yearly Class Hours per Student}}{\text{Average Section Size}}$$

$$= \frac{\sum_t \sum_i \sum_j Y(t,i,j) \Big/ \sum_t \sum_i E(t,i)}{A^*}$$

$$\text{Average Cost per Student} = \text{Average Faculty Instruction Cost per Staff-Contact Hour} \times \text{Staff-Contact Hours per Student}$$

$$\text{Average Cost per Student} = \frac{\text{Faculty Salary Load} \times \text{Faculty Instruction Factor} \times \text{Student Load}}{\text{Faculty Work Load} \times \text{Average Section Size}}$$

or

$$\bar{U} = \frac{\sum_j B(j) \Big/ \sum_j X(j)}{\sum_t \sum_i \sum_j H(t,i,j) \Big/ \sum_j X(J)} \times I^* \times \frac{\sum_t \sum_i \sum_j Y(t,i,j) \Big/ \sum_t \sum_i E(t,i)}{A^*} \qquad (11)$$

This form of the unit cost equation can be developed for the set of unit cost equations:

$$\bar{U}(t,i) = \text{unit cost in year } t \text{ of program } i$$

$$= \frac{\sum_{j} H(t,i,j) \times C(j)}{E(t,i)}$$

$$\bar{U}(t,i) = \sum_{j} \left[ \frac{B(j)/X(j)}{\sum_{t}\sum_{i} H(t,i,j)/X(j)} \times I(j) \times \frac{Y(t,i,j)}{A(t,i,j)} \right] \qquad (12\text{-a})$$

Where;

A(t,i,j) = average section size of courses taken by year t of program i from department j. This equals the total student hours taken by all students in year t of program i from department j divided by the total staff-contact hours provided for these students.

$$\bar{U}(i) = \text{unit cost in program } i$$

$$= \frac{\sum_{t}\sum_{j} H(t,i,j) \times C(j)}{\sum_{t} E(t,i)}$$

$$= \sum_{t}\sum_{j} \left[ C(j) \times \frac{H(t,i,j)}{E(t,i)} \right]$$

$$= \sum_{t}\sum_{j} \left[ \frac{B(j)/X(j)}{\sum_{t}\sum_{i} H(t,i,j)/X(j)} \times I(j) \times \frac{Y(t,i,j)}{A(t,i,j)} \right] \qquad (12\text{-b})$$

$$\bar{U}(t) = \text{unit cost in year } t$$

$$= \frac{\sum_i \sum_j [H(t,i,j) \times C(j)]}{\sum_i E(t,i)}$$

$$= \sum_i \sum_j \left[ C(j) \quad x \quad \frac{H(t,i,j)}{E(t,i)} \right]$$

$$\bar{U}(t) = \sum_i \sum_j \left[ \frac{B(j)/X(j)}{\sum_t \sum_i H(t,i,j)/X(j)} \times I(j) \times \frac{Y(t,i,j)}{A(t,i,j)} \right] \qquad \text{12-c}$$

The average section size A(t,i,j) is a very difficult factor to measure because it is necessary to know how many hours of instruction each student takes from each department. Instead a proxy measure can be introduced, A(t,i), which is an average section size for all departments.

$$A(t,i,j) = Y(t,i,j)/H(t,i,j)$$

$$A(t,i) = \sum_j Y(t,i,j) \Big/ \sum_j H(t,i,j)$$

This expression for average section size can be substituted into Equations 12-a, 12-b, and 12-c.

$$\bar{U}(t,i) = \frac{1}{A(t,i)} \sum_j \left[ \frac{B(j)/X(j)}{\sum_t \sum_i H(t,i,j)/X(j)} \times I(j) \times Y(t,i,j) \right] \qquad \text{13-a}$$

$$\bar{U}(i) = \sum_t \frac{1}{A(t,i)} \sum_j \left[ \frac{B(j)/X(j)}{\sum_t \sum_i H(t,i,j)/X(j)} \times I(j) \times Y(t,i,j) \right] \qquad \text{13-b}$$

$$\bar{U}(t) = \sum_i \frac{1}{A(t,i)} \sum_j \left[ \frac{B(j)/X(j)}{\sum_t \sum_i H(t,i,j)/X(j)} \times I(j) \times Y(t,i,j) \right] \qquad \text{13-c}$$

Further approximations for the average section size can be introduced into Equations 13-b and 13-c.

$$A(t) = \sum_i \sum_j Y(t,i,j) \Big/ \sum_i \sum_j H(t,i,j)$$

$$A(i) = \sum_t \sum_j Y(t,i,j) \Big/ \sum_t \sum_j H(t,i,j)$$

Equations 13-b and 13-c can be rewritten as:

$$\bar{U}(i) = \frac{1}{A(i)} \sum_t \sum_i \left[ \frac{B(j)/X(j)}{\sum_t \sum_i H(t,i,j)/X(j)} \times I(j) \times Y(t,i,j) \right] \quad \text{14-b}$$

$$\bar{U}(t) = \frac{1}{A(t)} \sum_t \sum_j \left[ \frac{B(j)/X(j)}{\sum_t \sum_i H(t,i,j)/X(j)} \times I(j) \times Y(t,i,j) \right] \quad \text{14-c}$$

To this point we have discussed only the Engineering component of unit cost. For other faculties, the instruction cost per staff-contact hour was developed by multiplying the average instruction cost per staff-contact hour for Engineering by the student to staff ratio in Engineering and dividing the result by the student to staff ratio for the whole university.

Then if;

$C^*$ = Engineering faculty instruction cost per staff-contact hour
$E(u)$ = university student population
$X(u)$ = total FTE staff in the university
$C_o^*$ = Other faculties instruction cost per staff-contact hour

$$= \text{Engineering Cost per Staff-Contact Hour} \times \frac{\text{Student-staff ratio in Engineering}}{\text{Student-staff ratio in the whole university}}$$

$$= C^* \times \frac{\sum_t \sum_i E(t,i)/X(j)}{E(u)/X(u)}$$

$$C_o^* = \frac{\left[\sum_j B(j) \Big/ \sum_j X(j)\right] \times I^* \times \sum_t \sum_i E(t,i) \Big/ \sum_j X(j)}{\left[\sum_t \sum_i \sum_j H(t,i,j) \Big/ \sum_j X(j)\right] \times E(u)/X(u)}$$

The unit cost expressions ($\bar{U}$, $\bar{U}(t,i)$, $\bar{U}(t)$ and $\bar{U}(i)$) must be adjusted to account for the cost of instruction provided by faculties outside of Engineering. If there are N departments in Engineering then the subscript j can assume values from 1 to N+1, where the $(N+1)^{st}$ department refers to all faculties other than Engineering. Then the unit cost in year t of program i for instruction taken from other faculties is equal to:

$$\text{Cost per Staff-Contact Hour} \times \text{Staff-Contact Hours per Student}$$

$$= C_o^* \times H(t,i,N+1)/E(t,i)$$

$$= C_o^* \times Y(t,i,N+1)/A(t,i,N+1)$$

where,

$Y(t,i,N+1)$ = student-hours taken by a student in year t of programme i from faculties other than Engineering

$A(t,i,N+1)$ = average section size of courses taken outside Engineering

For convenience, only the unit cost expression for $\bar{U}(t)$, the unit cost in year t of a program, will be developed further with the introduction of the cost of instruction taken in other faculties (from equation 13-c).

$\bar{U}(t)$ = unit cost in year t

$$= \text{Cost of instruction in Engineering} + \text{Cost of instruction from other Faculties}$$

$$= \sum_i \frac{1}{A(t,i)} \sum_{j=1}^{N} \left[ \frac{B(j)/X(j)}{\sum_t \sum_i H(t,i,j)/X(j)} \times I(j) \times Y(t,i,j) \right]$$

$$+ \left[ \frac{\left[ \sum_{j=1}^{N} B(j) \Big/ \sum_j X(j) \right] \times I^* \times \sum_t \sum_i E(t,i) \Big/ \sum X(j)}{\sum_t \sum_i \sum_{j=1}^{N} H(t,i,j) \Big/ \sum_{j=1}^{N} X(j) \times E(u)/X(u)} \times \frac{Y(t,i,N+1)}{A(t,i,N+1)} \right] \qquad (15\text{-}c)$$

(Equations 15, 15-a and 15-b would be the corresponding equations for $\bar{U}$, $\bar{U}(t,i)$ and $\bar{U}(i)$ respectively.)

The corresponding verbal expression for unit cost, averaged over all years and all programes ($\bar{U}$) would be;

$$\text{Average Cost per Student} = \frac{\text{Faculty Salary Load} \times \text{Faculty Instruction Factor} \times \text{Average Yearly Class Hours in Engineering per Student}}{\text{Faculty Instruction Work Load} \times \text{Average Section Size (Engineering)}}$$

$$+ \frac{\text{Faculty Salary Load} \times \text{Faculty Instruction Factor} \times \text{Average Yearly Class Hours Outside Engineering per Student}}{\text{Faculty Instruction Work Load} \times \text{Average Section Size (Other Faculties}} \qquad (15\text{-}d)$$

A single expression for average section size can be introduced which is measured for a whole program including instruction from both Engineering and other faculties.

$$\text{Average Section Size} = \frac{\sum_t \sum_i \sum_{j=1}^{N+1} Y(t,i,j)}{\sum_t \sum_i \sum_{j=1}^{N+1} H(t,i,j)} = \hat{A}$$

Using $\hat{A}$ as an approximation for both A* (the average section size in Engineering) and A(N+1) (the average section size of courses taught by faculties outside of Engineering) an approximation for Equation 15 can be developed.

$$\text{Average Cost per Student} = \frac{\text{Faculty Salary Load} \times \text{Faculty Instruction Factor} \times \text{Average Yearly Class Hours Per Student}}{\text{Faculty Instruction Work Load} \times \text{Average Section Size } (\hat{A})} \tag{16}$$

This expression employs five policy variables and the impact of each is plainly visible. For undergraduate programs, the total unit cost is obtained by applying the university overhead factor, a sixth policy variable. In this case university overhead is computed as the percentage of total ordinary operating expenditures required for academic expenses (salaries, equipment and furniture but excluding library expenses). Therefore, the total unit cost per undergraduate is:

$$\text{Total Undergraduate Unit Cost } (\bar{U}) = \frac{1}{Z} \times \frac{\text{Faculty Salary Load} \times \text{Faculty Instruction Factor} \times \text{Average Yearly Class Hours per Student}}{\text{Faculty Instruction Work Load} \times \text{Average Section Size}} \tag{17}$$

where Z = overhead factor

Comparable equations can be developed for all the unit cost expressions ($\bar{U}(t,i)$, $\bar{U}(t)$, $\bar{U}(i)$). For graduate programs, four components of unit cost were computed: instruction, graduate supervision, assisted research and university overhead. The factors affecting the instruction cost of graduate programs are similar to those for undergraduate programs, except that it is extremely difficult to define a student load in terms of yearly class hours since both the master's and doctoral programs were combined, and course work for these programs is normally unstructured. Instruction hours cannot be readily established without identifying the courses taken by each graduate student, a formidable task indeed. For this reason no attempt was made to analyze graduate student instruction costs. Furthermore, the instruction costs for graduate students were only a small portion of their total costs (5.5% average in Ontario).

Graduate supervision costs equal the graduate portion of the departmental budget divided by the appropriate number of graduate students. Therefore, the unit cost for a graduate student in department j can be developed as follows:

Let:

$\bar{U}_G(j)$ = unit cost of instruction in department j (comparable to $\bar{U}(i)$ in Equation 13-b)

$T_G(j)$ = total unit cost of a graduate student in department j

$R(j)$ = assisted research funds in department j

$$T_G(j) = \frac{1}{Z}\left[\bar{U}_G(j) + \frac{B(j) \times (1-I(j)) + R(j)}{G(j)}\right]$$

Thus, the seventh and eighth policy variables are the graduate instruction factor (equal to 1 minus the undergraduate instruction factor) and the total assisted research funds.

## 6. SUMMARY AND CONCLUSIONS

The policy variables that were identified in the last section can be used as a tool to control unit costs at any, or all, of the three administrative levels: university, faculty and department.

1. Salary Load (Budget per FTE staff) - Since the major portion of a departmental budget is salary, this quantity reflects the mixture of senior and junior staff in the department, the general age-experience profile and the current salary levels. This factor tends to be high for new institutions where attractive salaries and positions must be offered to attract qualified staff. As the university grows, this factor will tend to decrease, but when stability is achieved, it may increase as staff are promoted through the ranks. Therefore this factor can be controlled through salary increases, promotion and tenure policies and the use of part-time staff. For example, the use of part-time teaching staff from the profession should influence the factor in a downward direction.
2. Instruction Factor (Percentage) - This factor reflects the relative emphasis placed on undergraduate education. A low instruction factor shifts the expenditure from the undergraduate to the graduate sector. The instruction factor tends to decrease as the number of graduate students increases, and the result is that fewer hours can be devoted to instruction for a fixed total staff workload. This creates a need to reduce the number of sections leading to larger section sizes, particularly in the first and second year.
3. Student Load (Yearly hours of course instruction per student) - This factor represents the amount of time each student is required to spend in course instruction. Because of accreditation requirements and traditions, engineering programs tend to involve students in comparable instruction times and therefore this quantity exhibits the least amount of variation. Some of the variation may be accounted for by differences in the number of weeks in the academic year. Any adjustment of this variable must result from a value judgment related to the number of hours a student should spend in class as opposed to other activities.
4. Instruction Workload (Staff-contact hours per FTE staff) - This is only an approximate measure of the average faculty workload since no explicit recognition is given to administrative duties, community or counselling services. There is only limited control of this variable because of tradition and normal university practices. The use of junior

and part-time teaching staff, again consistent with good instruction, tends to increase this variable and thus to lower unit costs.

5. Average Section Size (Students per instructor) - This, the most important policy variable, is influenced by two major factors: sectioning policy and the number of courses offered in relation to the level of enrolment and number of available programs. In each case a value judgment is required to establish reasonable upper and lower limits. The use of the average section size concept provides a quantitative basis for assessing the impact of basic sectioning and elective policies on unit costs.

6. Graduate Instruction Factor (Percentage) - This is the complement of the instruction factor discussed under Item 2 above.

7. University Overhead Factor (Percentage) - This factor represents the distribution of funds between academic and non-academic expenditures, and normally is beyond the control of either the department or the faculty.

8. Assisted Research (Assisted research funds per graduate student) - Generally speaking, assisted research makes graduate programs possible. This factor is therefore of crucial importance, not in its effect on unit costs, but in its influence on graduate studies generally.

These variables give some insight into the influence of policies and practices on unit costs. What they do not give is an indication of quality. The elasticity of quality with each of these policy variables becomes a value judgment to be made by each university.

The general unit cost equation developed in Section 5 provides an example of how the policy variables can be changed to affect unit cost:

$$\text{Unit Cost} = \frac{\text{Faculty Salary Load} \times \text{Faculty Instruction Factor} \times \text{Student Load}}{\text{Overhead Factor} \times \text{Faculty Workload} \quad \text{Average Section Size}}$$

The following values can be substituted from the data for the undergraduate engineering programs in the model university:

| | | | |
|---|---|---|---|
| Faculty Salary Load | \$30,000 | Overhead Factor | 70% |
| Faculty Instruction Factor | .68 | Faculty Workload | 638 |
| Student Load | 882.5 | Average Section Size | 22.8 |

$$\text{Unit Cost} = \frac{\$30,000 \times .68 \times 882.5}{.7 \times 638 \times 22.8}$$

Unit Cost = \$1768 (cf. \$1779 in Table 6)

If the average section size was increased from 22.8 to 26 then the unit cost decreases to:

$$\text{Unit Cost} = \frac{\$30,000 \times .68 \times 882.5}{.7 \times 638 \times 26}$$

Unit Cost = \$1550

Table 6 is a summary of the policy variables affecting unit costs in Engineering for both undergraduate and graduate programs in the Ontario universities. The total unit costs for undergraduates, where programs were aggregated by year in each university, varied over a range of 17 to 1. Only the average section size had a variation of this magnitude. For this reason a regression to relate undergraduate total unit cost and the average section size was attempted. This is shown in Figure 7 where the least-squares fit is a hyperbola, as expected. The correlation coefficient of the linear transform was 0.89, and a total of thirty-nine data elements were used corresponding to each undergraduate year of each engineering program offered during 1969-70 in the eleven universities. A regression of average section size to unit cost, exclusive of overhead, should have been attempted but was not. A multiple regression to relate all of the policy variables to total unit cost was also not attempted.

The second most significant policy variable was the faculty instruction factor, which varied over a range of 4 to 1. This factor defines the relative emphasis placed on course instruction as opposed to graduate supervision, and becomes most important when comparing the relative costs of graduate and undergraduate studies in any university.

Next were the faculty salary load and faculty instruction workload variables, each spanning a range of about 3 to 1. Both of these variables depend on the number of FTE staff within Engineering, and

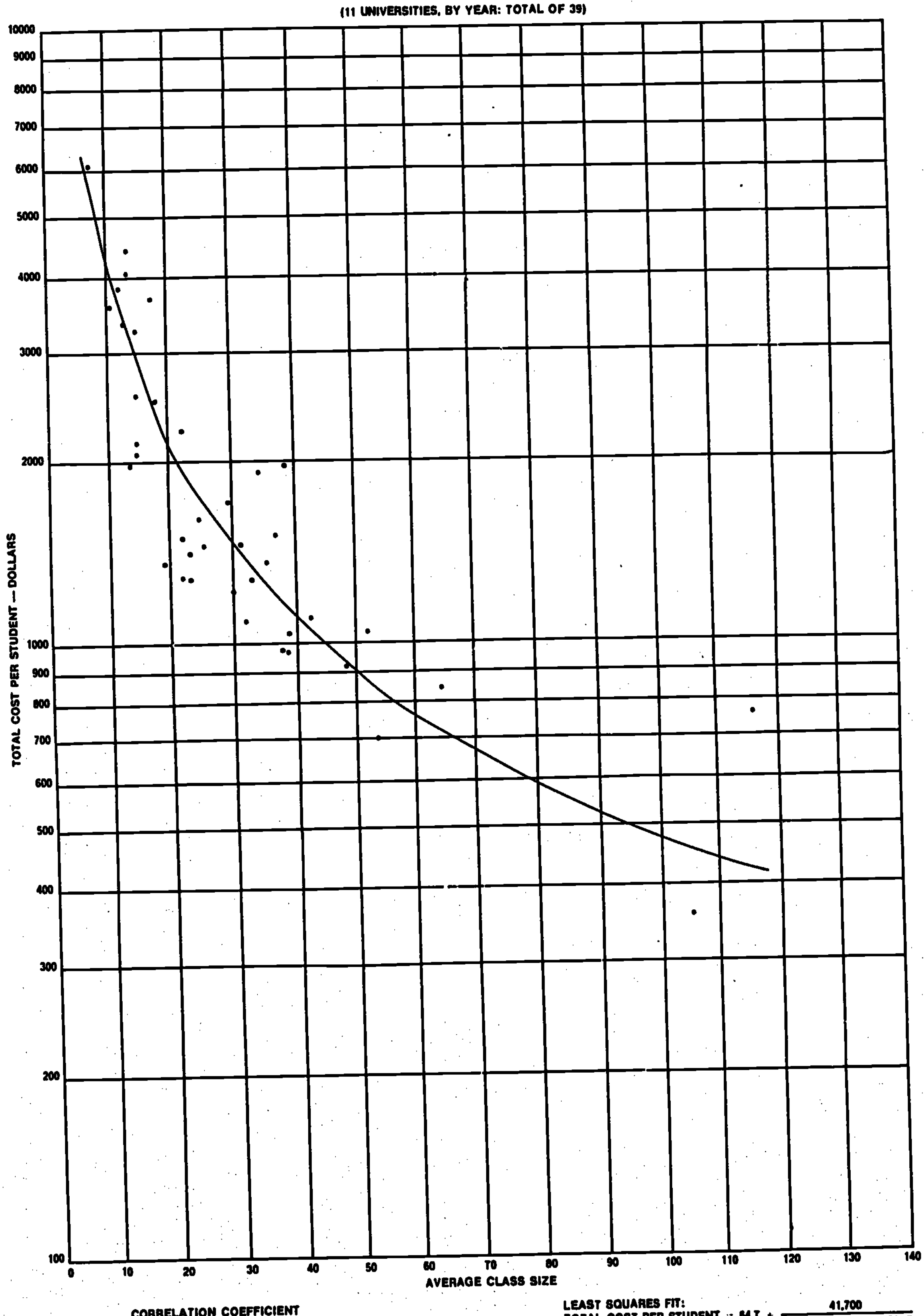
TABLE 6
POLICY VARIABLES - UNIVERSITY AVERAGES
1969-70

| NO. | POLICY VARIABLES | AFFECTS UNIT COSTS | | AVERAGED OVER | YEAR | ONTARIO AVERAGE | MAXIMUM | MINIMUM | MAXIMUM / MINIMUM |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Faculty Salary Load | Directly | $ per FTE staff | 11 Universities | All | 25,845 | 39,049 | 15,000 | 2.6 |
| 2. | Faculty Instruction Work Load | Inversely | Contact Hours Per FTE staff | 11 Universities | All | 293.96 | 495.89 | 157.71 | 3.1 |
| 3. | Faculty Instruction Factor | Directly | % | 37 Departments (1) | All | 39 | 59 | 15 | 3.9 |
| 4. | Student Load | Directly | Student Hours per Year | 11 Univ. (2) | I | 734 | 819 | 637 | 1.3 |
| | | | | 10 Univ. | II | 652 | 736 | 514 | 1.4 |
| | | | | 9 Univ. | III | 673 | 769 | 583 | 1.3 |
| | | | | 9 Univ. | IV | 691 | 801 | 574 | 1.4 |
| | | | | 11 Univ. | All | 689 | 819 | 514 | 1.6 |
| 5. | Average Section Size | Inversely | No. of Students per Instructor in Class | 11 Univ. | I | 51 | 116.4 | 25.9 | 4.5 |
| | | | | 11 Univ. | II | 32.8 | 63.8 | 7.5 | 8.5 |
| | | | | 9 Univ. | III | 21.3 | 36.5 | 12.9 | 2.8 |
| | | | | 9 Univ. | IV | 19.9 | 31.8 | 10 | 3.2 |
| | | | | 11 Univ. | All | 32.3 | 116.4 | 7.5 | 15.5 |
| 6. | University Overhead Factor | Directly | % | 11 Univ. | All | 30 | 38 | 21 | 1.8 |
| | Total Unit Cost Undergraduate | | $ per Student | 11 Univ. | I | 1110 | 1960 | 860 | 5.4 |
| | | | | 10 Univ. | II | 1670 | 6080 | 700 | 8.7 |
| | | | | 9 Univ. | III | 2140 | 3360 | 1170 | 2.9 |
| | | | | 9 Univ. | IV | 2450 | 4020 | 1080 | 3.7 |
| | | | | 11 Univ. | All | 1820 | 6080 | 360 | 16.9 |
| 7. | Graduate Student Factor | Directly | % | 37 Departments | All | 70 | 79 | 62 | 1.3 |
| | Total Unit Graduate Excluding Assisted Research | Instruction | $ per Student | 37 Departments | All | 1090 | 2410 | 90 | 26.8 |
| | | Graduate Supervision | | | All | 9460 | 14860 | 3860 | 3.8 |
| | | Total | | | All | 10550 | 17000 | 4370 | 3.9 |
| 8. | Assisted Research | Directly | $ per Student | 35 Departments | All | 6350 | 20420 | 1600 | 12.8 |
| | Total Unit Cost-Graduate Including Assisted Research | | $ per Student | 35 Departments | All | 16900 | 35290 | 8100 | 4.4 |

(1) 37 departments had graduate students in 1969-70. (2) of 11 universities. 2 offer years I and II only.

FIGURE 7 - AVERAGE SECTION SIZE - COST REGRESSION
ONTARIO ENGINEERING UNDERGRADUATE CLASSES 1969-70

(11 UNIVERSITIES, BY YEAR: TOTAL OF 39)




CORRELATION COEFFICIENT
OF THE LINEAR TRANSFORM, r = 0.89

LEAST SQUARES FIT:
$$\text{TOTAL COST PER STUDENT} = 64.T + \frac{41{,}700}{\text{AVERAGE CLASS SIZE}}$$

errors could have been introduced in the way they were reported by each university and counted for the purposes of this study. Fortunately, this counting does not affect unit cost calculations, since the number of FTE staff cancel in the division of these two factors. The remaining policy variables - university overhead factor and student load - vary over a range of about 2 to 1, and so were the least influential.

It should be noted that student load and instruction workload are not entirely independent. For example, if the academic year was extended by an extra week, both policy variables would increase in equal proportion. On the other hand, should extra classes be added to the student load, then the instruction workload may or may not increase. The extra staff load could be accommodated either by adding more staff or by increasing the workload of the existing staff.

The dominant impact on graduate student costs, excluding assisted research, was the graduate student factor. This resulted from the K factor analysis which concluded that each graduate student used 150 staff hours per year - an average for all of the engineering schools in Ontario. Where there is a relatively large number of course-work master's students, compared to thesis master's and doctoral students, unit costs would be disproportionately high. The reverse may be true where graduate thesis students predominate.

Assisted research accounts for about 40 percent of the total unit costs for graduate students and includes income from many sources. This additional cost would apply only to thesis students. It is an external policy variable, principally under the control of the National Research Council, that provides the major source of funds in response to proposals for research grants from the universities.

In general, program unit costs increased with the year level, principally because of the decrease in average class size in the later years as illustrated in Table 7. This reduction in class size is caused by decreasing enrolments due to attrition and the expansion of elective courses in many programs, particularly in the third and fourth year.

TABLE 7

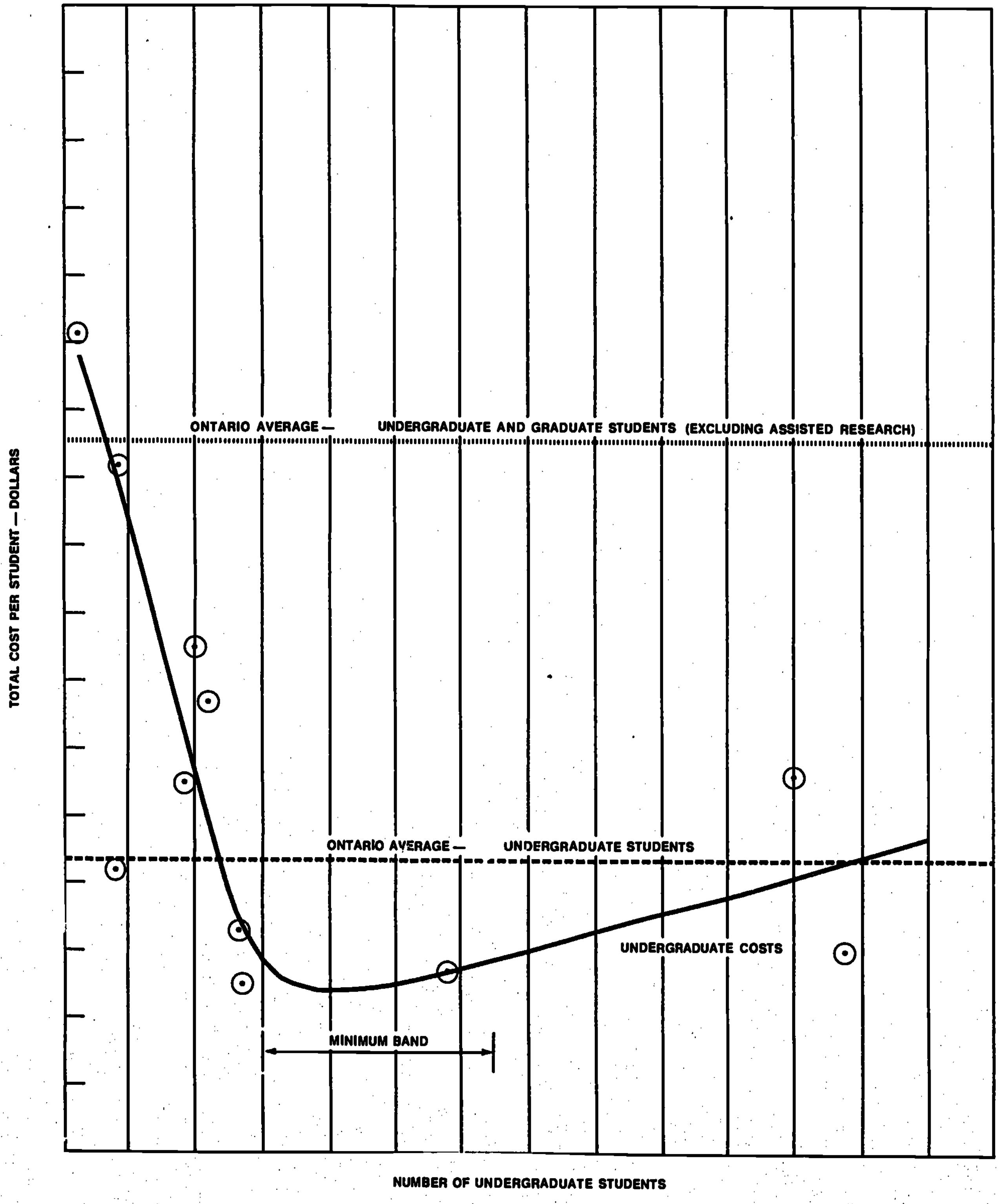
AVERAGE SECTION SIZE BY YEAR (UNDERGRADUATE)

| Undergraduate Year | Average Section Size (Ontario) | Number of Students in Sample |
|---|---|---|
| I | 54.5 | 2,621 |
| II | 34.3 | 2,450 |
| III | 21.3 | 1,709 |
| IV | 19.9 | 1,446 |
| All | 32.0 | 8,226 |

One important product of the cost study was the effect of engineering school size on unit costs. Figure 8 is a cost-size comparison, and shows how the unit cost varied with the number of students in undergraduate programs (eleven universities). It is difficult to draw firm conclusions with such a small number of points, but a trend appears to emerge; the curve exhibits a minimum band below which classes are small because they are student-limited. Within the band, classes reach a critical size, where sectioning becomes necessary. Beyond the band, sectioning policy is the main determinant, and as the school becomes very large, there appears to be a tendency to section into smaller classes. In the larger schools, more elective classes are offered in the third and fourth year, and this tends to keep average section size down even though total student numbers are relatively large.

From Table 5, it is possible to estimate very roughly the expenditure required for an engineering degree. A crude attrition model is assumed as follows: 75 percent second year survival from first year, 85 percent third year survival from second year, 90 percent fourth year survival from third year and 95 percent degree survival from fourth year. A conditional probability calculation was carried out using this model for the class of 1970. In round numbers, the expenditure to produce a graduate engineer in 1970 was about $8,000, provided the structure developed in the cost study did not alter appreciably over the previous three years.

FIGURE 8 - COST-SIZE COMPARISON
ONTARIO ENGINEERING SCHOOLS 1969-70



If attrition and discount are neglected for graduate students, the additional expenditure for a master's degree achieved in one year after the bachelor's degree was $8,190 (a total of about $16,000). For a doctorate achieved in four years after the bachelor's degree, there was an additional expenditure of $33,000 (a total of $41,000) excluding assisted research, or an additional expenditure of $54,000 (a total of $62,000) including assisted research.

## 7. OVERVIEW

Does this methodology for undertaking a cost study have universal applicability? In this study we have applied the method to a discipline within the Ontario university system. We believe the method should be valid for other disciplines provided there are sufficient data points to establish a value for the K factor. However, it is difficult to ascertain whether the method could be applied to a single institution because it would be necessary to assume a common relationship between the cost of a graduate student and the cost of a staff-contact hour for several disciplines in order to accumulate enough data points for the regression.

The major problem arises from the attempt to distribute a departmental budget between graduate supervision and formal instruction. This is the golden fleece that many Argonauts have sought. Whether or not we have been successful in coming closer to achieving that goal will be judged by time and future study.

The introduction of the policy variables and the unit cost equations should prove most useful to administrators.

In conclusion, we would wish to save future data combatants from having to wade through massive calculations and manipulations. After handling data sets for several weeks, it became evident that the calculations resolve to a few basic matrix multiplications. For the next adventurer these have been outlined in Appendix C. We do not mean to imply that the task of deriving unit costs has been reduced from its herculean proportions; budget and enrolment data must still be assembled, and a staff-contact hour matrix derived. But given these data sets, the task of producing unit costs should be lightened through matrix multiplication.

APPENDIX A

(Basic Data - Model University)

TABLE A-1

BASIC DATA - MODEL UNIVERSITY

FTE ENROLMENT

| | Year 1 | Year 2 | Masters | PhD | Total |
|---|---|---|---|---|---|
| General | 500 | - | - | - | 500 |
| Civil Engineering | - | 250 | 80 | 20 | 350 |
| Mechanical Engineering | - | 150 | - | - | 150 |
| Total Engineering | 500 | 400 | 80 | 20 | 1000 |
| Total University | N.A. | N.A. | N.A. | N.A. | 10000 |

N.A. - not applicable

Engineering FTE Staff - 50

University FTE Staff - 625

Length of Session - 25 weeks

TABLE A-2

COURSE ENROLMENT DATA

| Course | Given by the staff of the Dept. of | Number of sections | Given to students in | Number of students from each program | | | Total annual contact hours per student | | | Total annual staff hours per section | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Lec. | Lab. | Tut. | Lec. | Lab. | Tut. | Lec. | Lab. | Tut. |
| Structures | Civil | 5 | General-1* | 500 | | | 100 | | | 100 | | |
| Materials | Civil | 12 | General-1<br>Forestry-1 | 500<br>100 | 500<br>100 | | 100 | 100 | | 100 | 600 | |
| Water resources | Civil | 5 | Civil-2 | 250 | | 250 | 200 | | | 200 | | 200 |
| Steel structures | Civil | 5 | Civil-2 | 250 | 250 | | 100 | 150 | | 100 | 300 | |
| Transportation | Civil | 1 | Civil-Grad. | 10 | | | 100 | | | 100 | | |
| Systems dynamics | Mechanical | 10 | General-1 | 500 | 500 | | 100 | 150 | | 100 | 400 | |
| Vibrations | Mechanical | 10 | General-1<br>Physics-1 | 500<br>250 | 500 | | 100 | 150 | | 150 | 200 | |
| Materials science | Mechanical | 20 | Mechanical-2<br>Civil-2 | 150<br>250 | | | 100 | | | 100 | | |
| Fluid mechanics | Mechanical | 5 | Mechanical-2 | 150 | 150 | | 100 | 100 | | 100 | 600 | |
| Physical metallurgy | Met. & Mat. Sci. | 5 | Civil-2 | 250 | 250 | | 100 | 150 | | 200 | 500 | |
| Materials science | Met. & Mat. Sci. | 3 | Mechanical-2 | 150 | | 150 | 50 | | 100 | 150 | | 250 |
| Physics of metals | Met. & Mat. Sci. | 2 | Mechanical-2 | 150 | | | 100 | | | 100 | | |
| Statistics | Mathematics | 5 | General-1 | 500 | | 500 | 100 | | 100 | 100 | | 300 |

* refers to 1st year in the General Engineering program - based on the following format "PROGRAM - YEAR IN PROGRAM"

TABLE A-3

MODEL UNIVERSITY - BUDGET DATA

UNIVERSITY

Total academic expenditures as a percentage of total ordinary operating expenditures = 70%

FACULTY OF ENGINEERING

| Department | Academic Salaries $ | Other Expenses $ | Total $ | Assisted Research $ |
|---|---|---|---|---|
| Civil | 400,000 | 200,000 | 600,000 | 300,000 |
| Mechanical | 300,000 | 100,000 | 400,000 | - |
| Metallurgy and Materials Science | 150,000 | 50,000 | 200,000 | - |
| Faculty Administration | N.A. | N.A. | 300,000 | - |
| TOTAL | 850,000 | 350,000 | 1,500,000 | 300,000 |

N.A. - not applicable

APPENDIX B

(List of Symbols)

The following are the common symbols used in the report:

| | |
|---|---|
| $C(j)$ | instruction cost per staff-contact hour in department j |
| $H(t,i,j)$ | staff-contact hours devoted to year level t of program i by department j |
| $E(t,i)$ | enrolment in year level t of program i |
| $e(u)$ | enrolment for whole university |
| $D(t,i,j)$ | instruction cost per student in year level t of program i for department j |
| $G(j)$ | number of graduate students supervised in department j |
| $Q(j)$ | teaching equivalents in department j |
| $I(j)$ | instruction factor for department j |
| $S(j)$ | graduate student factor for department j |
| $B(j)$ | budget for department j |
| $X(j)$ | number of FTE faculty in department j |
| $X(u)$ | number of FTE faculty in the university |
| $T(t,i)$ | total cost of year t in program i |
| $\bar{U}(t,i)$ | unit cost of year t in program i |
| $\bar{U}(i)$ | unit cost in program i |
| $\bar{U}(t)$ | unit cost in year t |
| $\bar{U}$ | unit cost (averaged over all programs and years) |
| $C^*$ | faculty cost per staff-contact hour - Engineering |
| $C^*_o$ | faculty cost per staff-contact hour - other faculties |
| $I^*$ | faculty instruction factor |
| $Y(t,i,j)$ | yearly student hours by year t of program i from department j |
| $A^*$ | faculty average section size |
| $\hat{A}$ | average section size for a whole program |

| | |
|---|---|
| A(t) | average section size of courses taken by students in year t |
| A(i) | average section size of courses taken by students in program i |
| A(N+1) | average section size of courses taught by faculty outside of engineering |
| Z | overhead factor |
| $U_G(j)$ | unit cost of graduate instruction in department j |
| $T_G(j)$ | total unit cost of a graduate student in department j |
| R(j) | assisted research funds in department j |

APPENDIX C

(Unit Cost Analysis - Matrix Format)

UNIT COST ANALYSIS - MATRIX FORMAT(1)

<u>Given:</u> $k$ - scalar - the K factor

$H = (h_{ij})$ - staff-contact hour matrix $i = 1,n$
$j = 1,m$

$h_{ij}$ = staff-contact hours taught by department $j$ to program $i$

$$S = \begin{bmatrix} s_i & & & 0 \\ & \cdot & & \\ & & \cdot & \\ & & & \cdot \\ 0 & & & s_n \end{bmatrix}$$ - n x n diagonal matrix

$s_i$ = undergraduate students enrolled in program $i$

$$B = \begin{bmatrix} b_i & & & 0 \\ & \cdot & & \\ & & \cdot & \\ & & & \cdot \\ 0 & & & b_m \end{bmatrix}$$ - m x m diagonal matrix

$b_i$ = budget for department $i$

$$G = \begin{bmatrix} g_1 & & & & 0 \\ & \cdot & & & \\ & & \cdot & & \\ & & & \cdot & \\ & & & & \cdot \\ 0 & & & & g_m \end{bmatrix}$$ - m x m diagonal matrix

$g_i$ = graduate enrolment in department $i$

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(1) The authors are deeply indebted to Professor Bernard Etkin, Institute for Aerospace Studies, University of Toronto, who, when we were entangled in mathematical manipulations, showed us this shortcut, then reviewed this presentation and corrected our mistakes.

Define:

$$M = \begin{bmatrix} m_1 & & & & 0 \\ & \cdot & & & \\ & & \cdot & & \\ & & & \cdot & \\ 0 & & & & m_m \end{bmatrix}$$ - m x m diagonal matrix

$m_i$ = staff-contact hours taught by department i

$$E = \begin{bmatrix} e_1 & & & 0 \\ & \cdot & & \\ & & \cdot & \\ & & & \cdot \\ 0 & & & e_m \end{bmatrix}$$ - m x m diagonal matrix

$e_i$ = teaching equivalents for department i

$H^* = (h^*_{ij})$ - m x m rectangular matrix

$h^*_{ij}$ = staff-contact hours per student in program i taught by department j

$u = (u_i)$ - n x 1 column matrix

$u_i$ = unit cost of a student in program i

$c = (c_i)$ - m x 1 column matrix

$$C = \begin{bmatrix} c_1 & & & & 0 \\ & \cdot & & & \\ & & \cdot & & \\ & & & \cdot & \\ 0 & & & & c_m \end{bmatrix}$$ - m x m matrix

$c_i$ = cost per teaching equivalent in department i

<u>Therefore</u>:

$$e = m + kg$$
$$E = M + kG$$

$$H = SH^*$$

$$H^* = S^{-1}H$$

where,
$$S^1 = \begin{bmatrix} s_1^{-1} & & & & 0 \\ & \cdot & & & \\ & & \cdot & & \\ & & & \cdot & \\ 0 & & & & s_n^{-1} \end{bmatrix}$$

$$u = H^*c$$

$$H^* = S^{-1}H$$

$$u = S^{-1}Hc$$

$$B = CE$$

$$C = BE^{-1}$$

$$c = C\Lambda$$

where,
$$\Lambda = \begin{bmatrix} 1 \\ 1 \\ \cdot \\ \cdot \\ \cdot \\ 1 \end{bmatrix} \text{ - m x 1 column matrix}$$

$$c = BE^{-1}\Lambda$$

$$u = S^{-1}HBE^{-1}\Lambda$$

$$E = M + kG$$

$$\boxed{u = S^{-1}HB(M + kG)^{-1}\Lambda}$$

Note: the $i^{th}$ element of the diagonal matrix $(M + kG)^{-1}$ is

$$\begin{bmatrix} \bullet & & & & & \\ & \bullet & & & & \\ & & \bullet & & & \\ & & & (m_i + kg_i)^{-1} & & \\ & & & & \bullet & \\ & & & & & \bullet \\ & & & & & & \bullet \end{bmatrix}.$$